Network Working Group
Request for Comments #51

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4 May 70
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Proposal for a Network Interchange Language

Introduction

In this paper an attempt is made to specify a high level programming language for computer networks, and more specifically the ARPA network. The main concept introduced is the one of an abstract Network Machine, which is consistent with the idea of a HOST asking a service from the computer network considered as an overall computing facility. The dialogue is always between a HOST and the Network Machine which language is always the same, though its configuration may vary according to the real remote HOST.

From a programming language point of view, this concept is similar to the UNCOL proposed in 1958 [STR058] but never implemented, however, the application to a computer network implies a realtime interaction between programs. Also, the possibility for the user to use NIL either in a standard mode or in an extended mode where he defines himself his own entities should give to NIL a maximum of flexibility.

1. Basic concepts introduced in NIL

1.1 Aim of NIL

The two main objectives of NIL are:

a) to describe the environment in which a program is executed (its complement); this involves the description of:

- data formats and data structures
- exchanges with input and output devices and characteristics expected from them
- interface with operating system

b) to express the front end part of an interactive system:

The data flow through an interactive system generally decreases as the data reaches the kernel of the system: it is assumed that in many interactive systems a separable module exists or can be defined which involves a great amount of data exchanged with the user, and much less exchanged with the rest of the system. This module is called Front-End. It is important that the response time of the system is affected as little as possible by additional transmission delays. Also, it is desirable to keep the data rates as low as possible on the network.

It is assumed that the transfer of a Front End does not imply to solve the whole problem of program transferability.

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1.2 NIL subcategorization

As pointed out by S. Volansky [ ] it's convenient to divide languages in several sublanguages corresponding to their main functions. NIL is thus subdivided in:

- a control sublanguage
- an operation sublanguage
- a data declaration sublanguage
- an environment sublanguage

1.2.1 Control sublanguage

The control sublanguage states WHEN a computation is done: It describes the flow of control or ordering of the computations. With some information contained from the other sections of the language, it also states WHERE the computations are to be executed.

As a computer network introduces loose connections between several systems, the control language of the Network Machine should be able, in an elaborate version, of assigning computations to available processors, taking into account the time delays and resource allocation problems involved. It is not our purpose to consider this level at the moment.

1.2.2 Operation sublanguage

The operation sublanguage describes the operations to be performed on the data without indication of the sequencing between operations, it answers to the question of HOW an operation is performed. The operations are subdivided into two groups.

- a computation group
- a data manipulation group

The later is the most important part of NIL since its main purpose is the transformation of data structures and patterns.

1.2.3 Data declaration sublanguage

The data declaration sublanguage is necessary to declare the variables and data structures on which operations are performed.

The possibility is given to build structures of atomic elements called beads. NIL provides a standard set of beads used in the "standard mode" ; in the "extended mode" a user may define new beads and new structures of them.

1.2.4 Environment sublanguage

The environment sublanguage expresses the context in which a program expects to operate; expected characteristics of the peripherals, semantics of the exchanges with the outside world through a particular operating system.

Thus a complete "program descriptor" will contain four distinct sections:

environment section
data declaration section
control section
operation section

The identification section is omitted because it corresponds to the log in and socket grabbing part of the initialization procedure.

1.3 The Network Machine

One fundamental concept in NIL is that of an abstract Network Machine which has the following characteristics:

- an infinite memory: there is no problem of memory allocation or garbage collection in this machine. But as an item must be accessible, it must still have an address.

- variable word length: a word may be considered as the smallest intelligible and addressable item of data. The atomic element called bead is in fact the machine word. The structure and length of each type of beads are expressed in the data definition sublanguage.

As presented on figure 1.3.1, one HOST only communicates with a Network Machine which may operate in two modes.

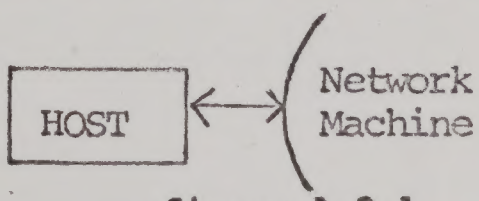

figure 1.3.1

- standard mode where the beads, ~~figuse~~ their structures, and the allowed transformations on them are standard and need not to be redefined: standard beads and structures are known of every HOST

- extended mode where in addition to or instead of the standard data definitions and manipulation, a HOST may specify new beads structures and transformations. The extended mode allows the user to define his own machine as the Network Machine. This is then equivalent to the modes MY LOCAL, YOUR LOCAL proposed in RFC #42 by Ancona. If the definition of a name has not been altered the standard definition is assumed.

The data definition sublanguage is as well used for the purpose of documenting the set of standard beads.

The instruction set of the Network Machine stands at a high level permitting global transformations of data structures.

The environment of the Network Machine is determined by the subset of the environment of the server's HOST which is used by the program in execution; the system HOST-Network Machine can take two main configurations shown in figure 1.3.2.

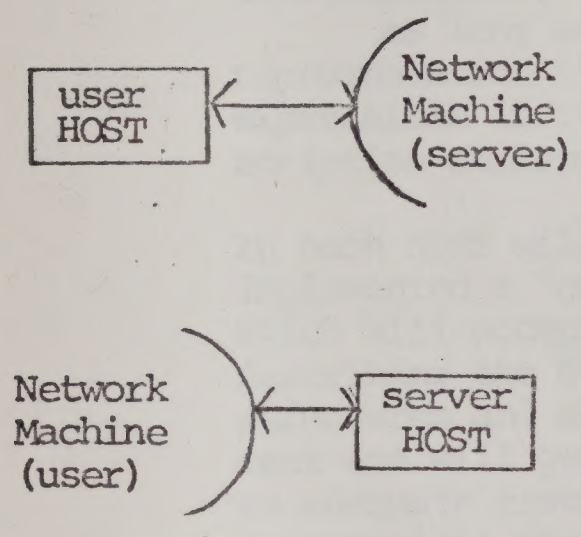

figure 1.3.2

a) The Network Machine stands for the user of a program provided by the HOST (server HOST)

b) The HOST machine is the user of a program provided by the Network Machine.

The server machine assigns its hardware environment to the user machine. This choice is made so that programs can be remotely used without being modified; it is up to the user of a remote program to adapt himself and his own environment.

Thus, when the Network Machine is server, it defines the Data Definition and Environment sections.

1.4 Implementation

The data and environment definition sublanguages should be able to describe as well environment and data in HOSTs as data in Network Machine. At the limit it should enable two programs written in different languages to communicate,

as long as the data representation they use are expressible in the data description sublanguage.

In each HOST will be implemented a "generator" which will accept rules describing the HOST data structures and environment and will generate an adequate translator to translate them in Network Machine format, as shown in the figure 1.4.1.

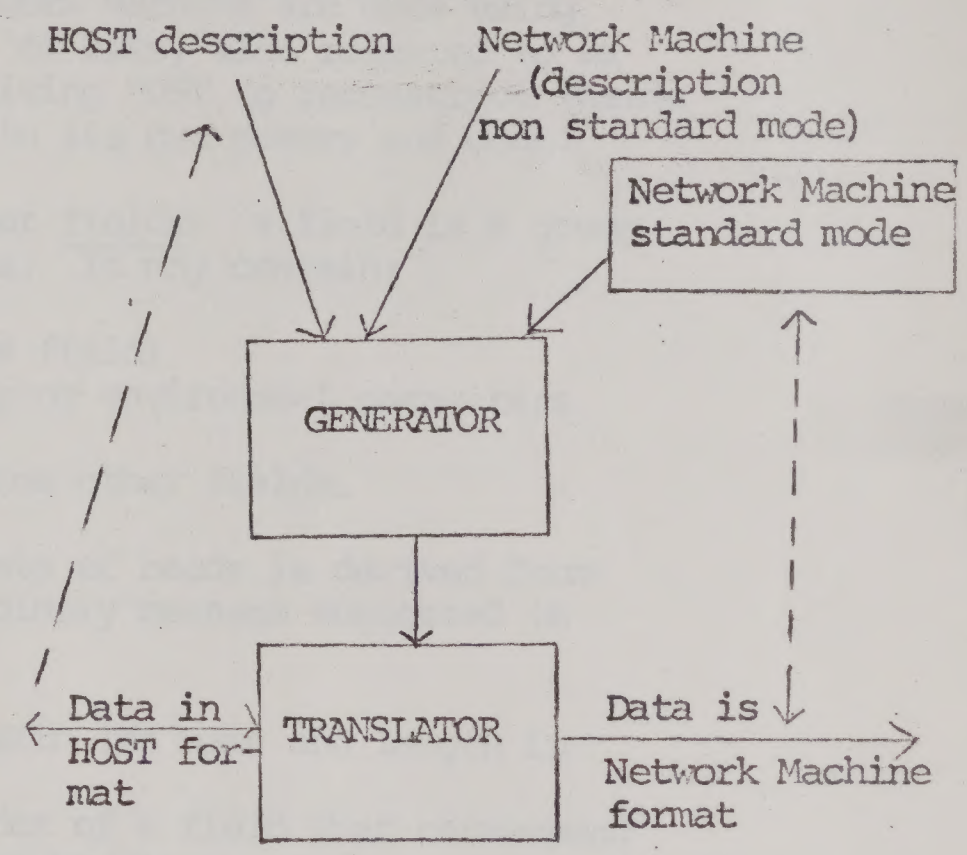

figure 1.4.1

Once the network machine standards will be settled it seems valuable to think about emulating the translator using a microprogramed unit which would be either added to the Host or rather to the IMP" thus avoiding the load of a translation which may involve lengthy operations on the bit level - (Figure 1.4.2.)

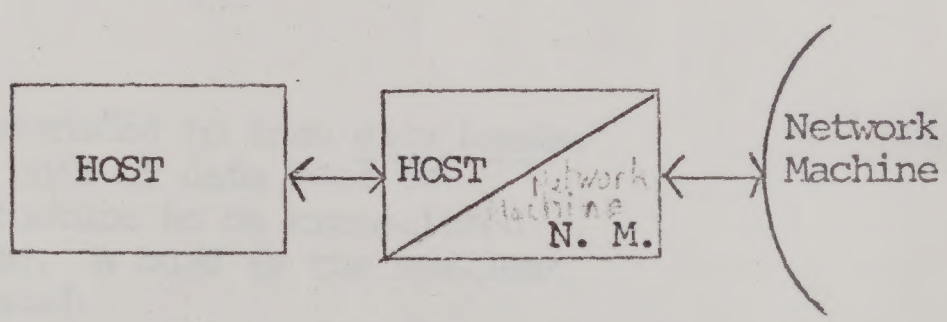

Figure 1.4.2

2. Data definition sublanguage

2.1 Fields

All communications with the Network Machine are done using strings of bits: these strings of bits, also referred to as messages are parsed by the receiving HOST to reconstruct inside its memory the data structures in its own memory and code.

Bits are grouped into significant fields: a field is a group of bits having definite contents. It may contain:

a) an element of data (data field)
b) some bit pattern specifying environment parameters
c) a pointer
d) the identification of some other fields.

The method to describe the formats of beads is derived from the method of description of a binary message suggested in RFC #31:

a) each field is declared with its name and length in number of bits.
b) commonly used fixed values of a field that correspond to a special meaning, may be given names.
c) legal ways of concatenating fields are initiated by rules; when only certain fixed values of a field are allowed, they may be either specified by their value or by the corresponding name.

2.2 Data beads.

Data fields (type (a)) are concatenated to form data beads: a bead is an indivisible atomic unit of data used as building element of any data structure to be transmitted between HOSTs and Network Machine. A bead is the smallest unit of data that can be referenced.

The legal ways of forming a bead by concatenation of several fields are indicated in a construction rule. Beads have a fixed length and an unambiguous structure. In real machine beads are usually defined as an integer number of contiguous registers. This constraint does not apply here, though it may turn out to be more efficient to favor HOSTs with, for instance, 32 bit words, and 4 bytes per word, which are the most common word structure on the ARPA network.

Data beads may be considered as the operands of the language in which fields of type (b) and (c) would be operators.

2.3 Control fields

The way data beads are linked one to the other and the environment in which they operate are specified by additional control fields which cannot be referenced and are operators on or identifiers of the following string of beads, or linkage between individual beads.

The scope of a control field may as well be all the beads or substructures of a structure, if it is specified at the level of the head of the structure. To be more precise, two kinds of structures of beads must be defined: homogeneous and heterogeneous structures.

A structure is defined as homogeneous if both a unique type of bead and a fixed parameter environment for the whole structure is specified at the head of the structure.

A structure is defined as heterogeneous if at least one of the following conditions is true.

- different types of beads are used for building the structure
- the environment in which lie the beads of the structure is changing within the structure.

Five main control fields need to be defined.

a) MODIFY
b) FLAG
c) POINTER
d) IDENTIFICATION
e) PARAMETER

2.3.1 MODIFY field

The MODIFY field is a one bit field preceding every bead of a heterogeneous structure: it is a flag set when followed by one or several control fields of type b, d, or e, which aim at modifying either the environment of data beads or their type. This field has the value:

1 if the attached data bead type and its environment do not change
0 if the attached element is a control field or a sequence of control fields of type b, d, or e specifying a change in type/or environment of following data beads.

2.3.2 FLAG field

When set, the MODIFY field is immediately followed by an 8 bit FLAG field indicating which of the IDENTIFICATION and several possible PARAMETER fields are present; when set to one each individual bit means the following:

bit number	
0	IDENTIFICATION field present
1	first parameter field present
2	second parameter field present

6	sixth parameter field present
7	next field, is another FLAG field for some more parameters (in case more than 6 parameters may be attached to a bead environment).

2.3.3 POINTER field

The number and nature of pointers to be attached to each bead depends on the structure definition. A given list structure may need one forward pointer. A ring structure may use an additional pointer to the first element. The necessary linkage between beads are defined in the structure definition thereafter the necessary pointer fields automatically added to each data bead. A bead is referenced within a structure by an address relative to the head of the structure. Thus a 16 bit pointer field should be fully sufficient to contain this address.

2.3.4 IDENTIFICATION field

The IDENTIFICATION field is an 8 bit field which identifies a bead type among the list of defined bead types. Standard bead types are numbered from zero up and non-standard bead types are numbered from 255 down. The non-standard types numbering is special to each server program or to a set of server programs. The IDENTIFICATION fields follow a MODIFY field of value 1 whenever the bead type has not been defined all over the structure in the structure root. Identification fields are also used at the level of the head of the structure to specify the type of identical elements (beads or structures) used within this structure.

2.3.5 PARAMETER field

The PARAMETER field gives the list of the environment parameters in which the following string of data beads lies. A PARAMETER field is specific of a bead type; it directly follows the MODIFY field when there is no ambiguity or the type of the next data beads.

Example: the parameter field of the standard bead BEAMMVT will contain the following fields.

- a 2 bit field indicating the type of movement generated

00	do not display	move the beam
01	display final point	point
10	display vector	vector
11	unused	

- a 4 bit field indicating beam intensity, by a number from 0 to 15, 0 meaning a null intensity, and 15 the maximum possible intensity.

- a 1 bit field for blinking

  0 off
  1 on

- a 1 bit field for light pen sensitivity

  0 off
  1 on

2.4 Metalanguage definition

A COBOL - report like meta language is used in the examples because of its readibility, as well in the beads as in the structure definitions.

Symbol	Meaning
+	concatanation
{ }	choice
[ ]	optional choice
$\{\ \}^{l \le n \le u}$ $[\ ]^{l \le n \le u}$	repetition

l lower bound on the number of identical items; if omitted l is assumed to be 0.

u upper bound on the number of identical items; if omitted u is assumed to be ∞.

a number alone means: exact number of repetition.

:	label for further use within the same rule
=	assignment
= ⊃	conditional alternative
( )	grouping
' '	indicates a special value given to the following field name
⊕	plus
⊖	minus

2.5 Proposed standard beads

2.5.1 Alphanumeric beads

Character: CHAR

A character is composed of one eight bit field (which has the same name). Many special patterns, corresponding to currently used special characters are defined; they are indicated in table 2.5.1, as well as some subsets of CHAR. The basic character code is declared as standard ASCII
standard EBCDIC
or by the name CODE
followed by the 128 characters in this code corresponding to the 128 ASCII characters. If no code declaration is specified, the ASCII code is assumed by default.

Number representation

Normally the kernel of a program stays in the server's HOST and the user's HOST should have no arithmetic operations to perform on the data. In this case, the principles involved in the arithmetic unit conception of a HOST do not need to be described. But the format of fixed and floating point numbers has to be described.

- in the case when user and server HOST's have the same number representation,for instance the standard representation,the transmission of data in their number representation reduces the data flow between them.

- if the server HOST has a different number representation than the standard representation, depending on the data transmitted, there are two alternatives:

+ the numerical data is exchanged as decimal numbers in the standard code

+ the fixed and floating point format are defined to the Network Machine and the user HOST performs

either a direct transcoding from the server binary representation to decimal representation and vice versa.

or a transcoding from the server binary representation to its own binary representation and vice versa.

As most of the numbers exchanged are to be printed in decimal or are given as decimal input, it is felt that when there is incompatibility between binary representations of corresponding HOSTs, exchanges in decimal representation would be the easiest.

Thus are defined:

a) Number in decimal representation which is not a bead but a string of characters (see 2.3.1)

b) Fixed point numbers single precision FXPNUM1
double precision FXPNUM2

Field definition	BYTE	8	SIGN	1
	SBYTE	7		

FXP NUM1 ← SIGN + SBYTE + $\{BYTE\}^3$

FXP NUM2 ← FXPNUM 1 + $\{BYTE\}^4$

c) Floating point numbers single precision FLPNUM1
double precision FLPNUM2

FLP NUM1 ← SIGN + SBYTE + $\{BYTE\}^3$

FLP NUM2 ← FLPNUM1 + $\{BYTE\}^4$

This only expresses the syntax of the floating point number. The semantics should say: in FLPNUM1

SIGN is the sign of the number of format $\{BYTE\}^3$ which is the mantissa

SBYTE is the exponent, and its value is based by a value of 40_{16} to insure positive exponents. In fact, FXPNUM1 and FLPNUM1 differ by their semantics.

These properties will be expressed by special field definition:

$$EXP \leftarrow SBYTE \oplus '40H' SBYTE$$

$$MANT \leftarrow SIGN \oplus \{BYTE\}^3$$

and a floating point number is defined as:

$$FLP = MANT \quad 2^{EXP}$$

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1. Special Characters

Transmission Control Characters

SOH
STX
ETX
EOT
ENQ
ACK
DLE
NAK
SYN
ETB
ESC

Printer Control Characters

horizontal tabulation	HT	←	'0X1' CHAR
vertical tabulation	VT	←	'0BX' CHAR
new line	NL	←	'0AX' CHAR
end of message	EOM	←	'08X' CHAR

Teletype Control Characters

Carriage return	CR	←	'0DX' CHAR
shift out	SO	←	'0EX' CHAR
shift in	S1	←	'0FX' CHAR
	BS	←	

Device Control Characters

DC1
DC2
DC3
DC4

Table 2.3.1

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2. Subsets of Characters

Numeric characters

NUM ← { '1', 2, ., ., ., '9' } CHAR

Printable characters

PRCHAR ← { NUM, ALPH, = } CHAR

Intermediate characters

ITCHAR ← { 'characters in column 2' } CHAR

Final Characters

FIN CHAR ← CHAR ⊖ ITCHAR

Transmission Control Characters*

TRACHAR ← { 'NUL', ., ., ., DEL } CHAR

Derra Control Characters

DCCHAR ← { 'DC1', DC2, DC3, DC4 } CHAR

Teletype control character

TYCCHAR { CR, SO, SI, BS }

Alphabetic characters

ALPH ← { 'A', ., 'Z' } CHAR

Printer Control Characters

PCCHAR ← { HT, VT, NL, EOM } CHAR

Table 2.3.1: Special ASCII characters and groups of ASCII characters.

*see USACII standards

2.5.2 Graphic Beads

As proposed in RFC #5 by J. Rulifson, the screen of any graphical display is taken to be a square; the coordinates of points are normalized from -1/2 to +1/2 on both axes. The position of the first point of a structure is determined by the deflection from the origin which is the rest point of the beam; following points are determined by their deflections (AX,AY) from the last beam position.

Thus, only two data fields need to be defined:

DEFLECTION which is a 12 bit field: the deflection is defined by a number between - 1 and +1 with the precision usual to the server.

ANGLE which is a 15 bit field defining an angle from 0 to 2Π in radians between the horizontal axis and an axis passing through the origin. The first bit of it indicates if the angle must be taken clockwise or counterclockwise.

The data beads are:

MOVE

Depending on the parameters which are set when this bead appears, MOVE may specify:

- an invisible movement of the beam; in this case the beam intensity is null

- a new point: in this case the beam intensity is on only when the beam has reached the new point.

- a vector: in this case thebeam intensity is set to a certain non zero value

MOVE ← {DEFLECTION}^{2}

Arc of circle: ARC

An arc of circle is defined by its center, followed by its starting point and the angle of its ending axis.

ARC ← {DEFLECTION} ^{4}+ANGLE

2.6 Proposed parameter fields.

2.6.1 Character strings.

In character strings some of the control characters are really parameter fields: they act as an operator on the following string of characters. i.e.:

lower shift
upper shift
new line
escape
. . . .

But as the code and use of these characters are determined in the standard codes, they are not included in parameter definition. It may be taken advantage that these characters are in the two left columns of the ASCII or EBCDIC standard code: they correspond to codes with the first three bits null in EBCDIC and the first two bits null in ASCII.

2.6.2 Graphics parameters

The following parameter fields are defined:

scale	SCALE		4
beam intesity	INT		4
light pen sensivity	SENS	←	SWITCH
blinking	BLINK	←	SWITCH
beam	BEAM	←	SWITCH

SWITCH is a 1 bit field which may take the values:

ON ← '1' SWITCH
OFF ← '0' SWITCH

A switch parameter stays ON, as long as it is not reset to OFF.

The beam intensity is expressed by a number from 0 to 1. 0 is black and 1 as light as the display can go. Numbers in between specify the relative log of the intensity difference. BEAM permits to switch the BEAM on or off without changing the Current INT parameter.

2.7 Structures

2.7.1 Structure definition.

The structure definition consits mainly in the specification of the topological relations between data beads:

- sequential relations; no pointer field necessary
- links through a number of pointers.

2.7.2 Standard structure type.

Two basic standard structure types are chosen

VECTOR to represent sequence of data beads (strings, arrays, tables...)

PLEX to represent any kind of directed graph, tree, ring...)

VECTOR $(C;N,\ldots N_C) \leftarrow$ VECTORHDR + VECTORBODY

VECTORBODY $\leftarrow$ (=C+1:{defined bead}^{Ni} + [VECTORBODY]

VECTORHDR $\leftarrow$'VECTOR' IDENTIFICATION + C + N_1 + N_2 + ... +N_C

C is the number of parts (columns) in the vector, each part having N_C elements.

It is also probably interesting to define a compressed vector COMPVECTOR in which sequence of the identical elements are transmitted as 1 element + a special bead + the number of identical elements in sequence.

PLEX (M)

The first bit of a pointer field indicates if the pointer points to a terminal element or not. If it is the case, forward pointer fields are not added to the data element.

M is the number of data elements in the structure.

2.8 Objects

2.8.1 object definition.

An object is defined by a semantic rule including, on the right hand side
- a name to identify the object
- a set of parameters of the object definition.

on the left hand side
- operands: name of the beads used as data elements
- operators: parameter fields
- structure of the data beads.

i.e. The definition of a new object called SQUARE is: SQUARE $\leftarrow$ (A,L,Aθ) ROT(A,ANGLE θ) (VECTOR(1,4) (BEAM'OFF'+ MOVE (A) + BEAM 'ON' + MOVE (0,L) + MOVE (L,0) + MOVE (0,εL) + MOVE (εL,0))

Where ROT refers to a transformation defined in the data manipulation language, and VECTOR is defined as a standard structure.

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The identifier of the new structure is SQUARE
The structure type used is VECTOR with dimension 1 and 4 elements
The elements of the VECTOR are standard beads MOVE
The parameters are A, L, and A θ
Parameter fields BEAM 'OFF' and BEAM 'ON' are used.

2.8.2 Alphanumeric standard objects.

Compressed character string (COMSTRING)

$$\text{COMSTRING} \leftarrow \text{VECTOR (1)} \left(\left\{ [\text{PRCHAR}]^{n} + \begin{bmatrix} \text{HT+NUM} \\ \text{VT+NUM} \\ \text{ESC+CHAR} \\ \text{NL} \\ \text{EOP} \end{bmatrix} \right\}^{n} \text{EOF} \right)$$

A compressed string of characters is any number of times a string of any number of printable characters followed by one of the following characters

- horizontal tabulation followed by the number of corresponding blanks to be added
- vertical tabulation followed by the number of lines to be skipped.
- escape followed by any character
- new line
- end of page

The compressed string is ended by an EOF character.

- Code table (CODE)
  CODE←VECTOR (1;128) $\{\text{CHAR}\}^{128}$

CODE is the name of the translation table assumed for a given program. When defined by the user, he must give from column 1 to column 8 the 8 bit pattern equivalent to the corresponding ASCII code.

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- Binary card image

$$\text{B CARD} \leftarrow \text{VECTOR } (1;120) \ \{\text{CHAR}\}^{120}$$

Packed decimal number HNUM 4 bits field

$$\text{DSIGN} \leftarrow \left\{ \begin{matrix} A & X \\ C & X \\ E & X \\ F & X \\ B & X \\ D & X \end{matrix} \right\} \text{HNUM} \qquad \text{PNUM} \leftarrow \left\{ \begin{matrix} 0 & H \\ \vdots & \\ 9 & H \end{matrix} \right\} \text{HNUM}$$

$$\text{PDNUM} \leftarrow \{\text{PNUM}\}^{1<n<31} + \text{DSIGN}$$

- Decimal number (unpacked or zoned

$$\text{DNUM} \leftarrow \{\text{NUM}\}^{1<n<31} + \text{D SIGN} + \text{PNUM}$$